# EVALUATION REPORT

## Enhancing the Global Situational Awareness Tool with Output from the Malaria Modeling and Surveillance Project

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# INTRODUCTION

Malaria has been with the human race since ancient times. Currently, about 40% of the world's populations live in regions endemic with malaria. Worldwide, there are approximately 300–500 million cases and at least 1 million deaths in any given year. In an endemic area, the local adult population may acquire sufficient immunity after repeated infections, and is less likely to develop severe symptoms if infected. Because malaria is virtually non-existent in the U.S., Americans traveling to the malaria endemic regions are particularly at risk. Consequently, malaria is a disease of paramount concern to the U.S. military. Being the first to be deployed in most contingencies, the U.S. Special Operations Forces are especially vulnerable to infectious diseases like malaria.

In the Malaria Modeling and Surveillance (MMS) project, within the NASA Applied Sciences Public Health Program, we have been pursuing remote sensing based techniques and models for malaria risk assessments and control. The goal of the Applied Science Program is to benefit society using NASA data, technologies, models, and results.

The Global Situational Awareness Tool (GSAT) is a system developed by the Air Force Special Operations Command (AFSOC) for assessing environmental and health issues of concerns for deployed U.S. forces. The NASA and AFSOC teams first met in February, 2004 at the Tri-Service Entomological Conference in Jacksonville, Florida. It was thought that the two projects had compatible goals and that the GSAT might benefit from the MMS project's malaria risk assessments. A subsequent meeting was held at Stennis Space Center in August, 2004.

# OVERVIEW OF GSAT

GSAT was preceded by a prototype, proof-of-concept system called the Global Operational Environmental Review (GOER). In 2001, GOER successfully passed an extensive operational utility evaluation performed by the 18th Flight Test Squadron at Hurlburt Field, Florida. The GOER prototype was awarded an Air Force (AF) Best Practice by judges of the 2002 AF Chief of Staff Team Excellence Award Competition. GSAT expands and improves on GOER's capabilities. The GSAT system, shown in Figure 1, will be fully developed to provide support to AFSOC and other AF users worldwide. The GOER was used on a limited basis in Operation Enduring Freedom (2001–2002) and Operation Iraqi Freedom (started in 2003).

GSAT is a computerized set of linkable databases with an intelligent “data-mining” tool and a user-friendly interface. Suppliers of data for GSAT, in addition to NASA, are expected to be government agencies such as the Army’s Center for Health Promotion and Preventive Medicine (CHPPM), United States Geological Service (USGS) and the Centers for Disease Control (CDC). These organizations provide certified, reliable data that GSAT can tap and analyze. Horizontal integration and data sharing with other tools, such as GeoReach, will provide additional capability. Later, spiral developments will build from this initial data linkage capability.

GSAT is a knowledge or rule based system. The knowledge-based rules are written to achieve outcomes that human experts achieve doing similar analysis. Rules development is the responsibility of HQ AFSOC/CEV. The rules are developed by teams of subject matter experts (SMEs) at development conferences. SMEs include military planners, operators, scientists, public health experts, physicians, and appropriate experts necessary to ensure success. The experts identify various environmental parameters, and mission activities, and logically determine the impacts on the mission. The rules provide output mitigation statements. The rules are written in *‘If…, then…’* format. For example, *‘If the Operation occurs in April, and model predicts malaria; then…(output). Bring mosquito netting, DEET repellant, and inoculate troops prior to deployment.’* The results from the MMS Project will be an essential element in deriving the rules.

# OVERVIEW OF MMS

The objectives of the Malaria Modeling and Surveillance Project are: 1) to assess malaria risks based on climatic and environmental variables, 2) to identify potential malaria vector larval habitats for targeted vector control , and 3) to dynamically simulate malaria transmission when more detailed epidemiological information are available, for selected regions of the world. The value and benefits of the project are: 1) reduced morbidity and mortality for U.S. overseas forces, 2) improved public health for local populations, 3) reduced damage to the environment, and 4) reduced likelihood of larvicide, insecticide, and antimalarial resistance.

For areas in Asia, the MMS Project now has the preliminary capabilities for 1) estimating current malaria risks based on climatic and environmental variables, 2) forecasting future malaria risks based on NASA climate prediction, 3) identifying potential malaria vector larval habitats, and 4) dynamically simulating malaria transmission under the influences of intrinsic and extrinsic factors. These capabilities will be further developed to meet AFSOC’s needs.

# NASA DATA AND RESULTS TO BE USED IN MMS

For assessing current, and predicting future, malaria risks, the NASA Earth–Sun science data sets shown in Table 1 will be used. For regions outside of the coverage areas of the Tropical Rainfall Measuring Mission (TRMM), precipitation data will be obtained from the Special Sensor Microwave Imager (SSM/I) data set. After the TRMM service is ended, SSM/I data will be the replacement. Relative humidity can be computed or obtained from other data sets. The climatic and environmental data for modeling malaria risks will be offered to AFSOC, if needed, in addition to the assessed risks.

For detecting potential larval habitats, we will use data from the Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) instrument, Earth Observing-1 (EO-1) satellite, or Landsat for larger habitats, and commercial data, such as IKONOS and QuickBird for smaller habitats. Because tasking commercial satellites for new data is normally expensive, only the data that were already acquired will be used. Identification of potential larval habitats is only intended for selected areas with special public health or strategic needs when elevated malaria risk is anticipated.

Mosquito larvae depend on water to survive. Surface wetness is, therefore, important to malaria transmission. We have not, however, included surface hydrological parameters in our models because of the following reasons. 1) Spatial resolution of directly remotely-sensed hydrological variables is too low for modeling (e.g., $25 \times 25$ km$^2$ for the Advanced Microwave Scanning Radiometer (AMSR) measured soil moisture). 2) Modeled surface moisture is driven by the Digital Elevation Model (DEM), whose current resolution outside of U.S. (90 m based on the Shuttle Radar Topography Mission measurements) is too low for effective modeling larval habitats. Because smaller larval habitats are usually more productive, these productive habitats would be overlooked. 3) Using the DEM-based model at current resolution implies that larval habitats do not exist at higher elevations. This assumption is not valid, as fish ponds and terraced rice fields (both are important larval habitats) in the mountains are common in many parts of the world. The NASA team, however, will help AFSOC to obtain AMSR-E data over the malaria risk assessment regions if these data are useful for GSAT.

# NASA DATA AND RESULTS TO BE PROVIDED TO GSAT

The NASA data and results to be provided to GSAT include:

- The satellite derived meteorological and environmental parameters,
- Malaria risk maps for selected regions of the world. The regions are jointly agreed upon by AFSOC and NASA teams, and
- Potential malaria vectors' larval habitats for selected areas.

# INTEGRATED SYSTEM SOLUTION DIAGRAM

An Integrated System Solution Diagram illustrating how the GSAT may be enhanced with malaria related capabilities is shown in Figure 2.

# CONCLUSION

As discussed above, the goals of AFSOC's GSAT and NASA's MMS Projects are clearly compatible. The NASA data, results, and the output from MMS will be able to enhance GSAT's capability.

The NASA team will further develop its malaria modeling capabilities to assess malaria risks for regions of interest to AFSOC, while the AFSOC team will integrate malaria risks and NASA Earth-Sun science data into GSAT. A systems engineering approach, including verification and validation, and benchmarking, will be followed. Performance of the GSAT with malaria risks incorporated will be evaluated by real users and the AFSOC 18th Flight Test Squadron for reliability and accuracy. The GSAT will also be tested in real military exercises such as joint forces exercises (JFEX)'06 or JFEX'08. As AFSOC has started preparing for JFEX'06 already, the NASA team has recently transmitted certain data sets to AFSOC to be used in a version of GSAT for JFEX'06.

When GSAT is fielded, the Air Force will gain a computerized environmental and medical planning capability. The combined capabilities of the malaria assessments and GSAT shall provide the U.S. Air Force, Department of Defense, and its partners with a decision support tool valuable to U.S. military and civilian sectors. Such capabilities will undoubtedly also benefit the public health of the local populations through U.S. personnel.

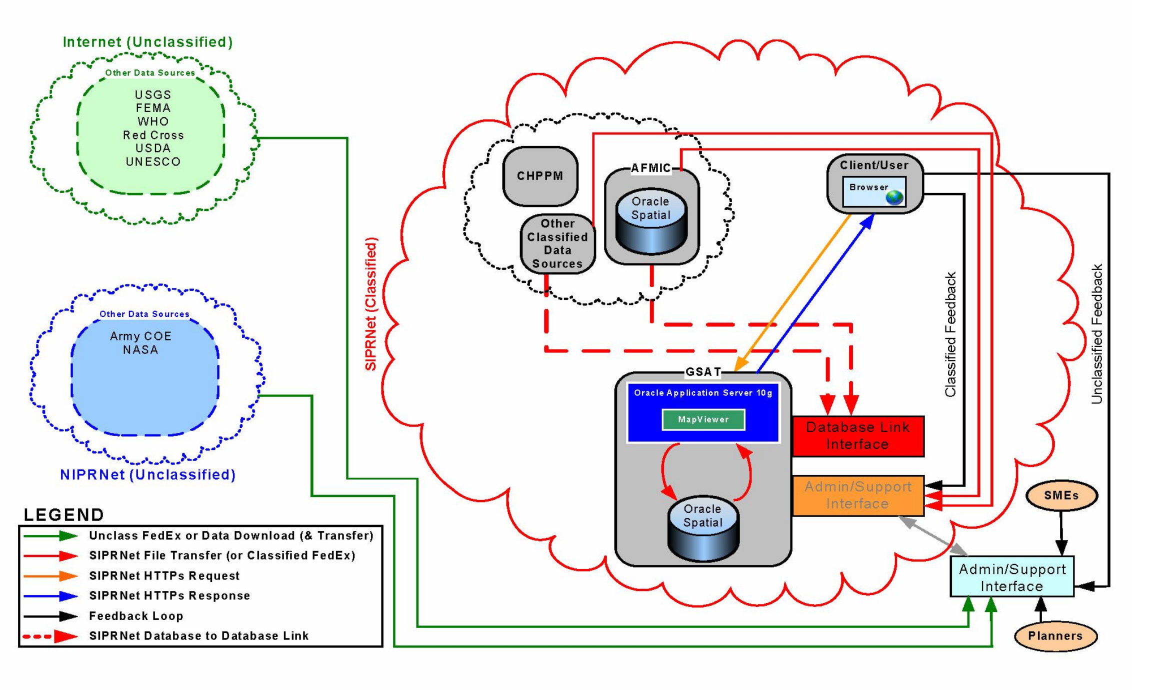
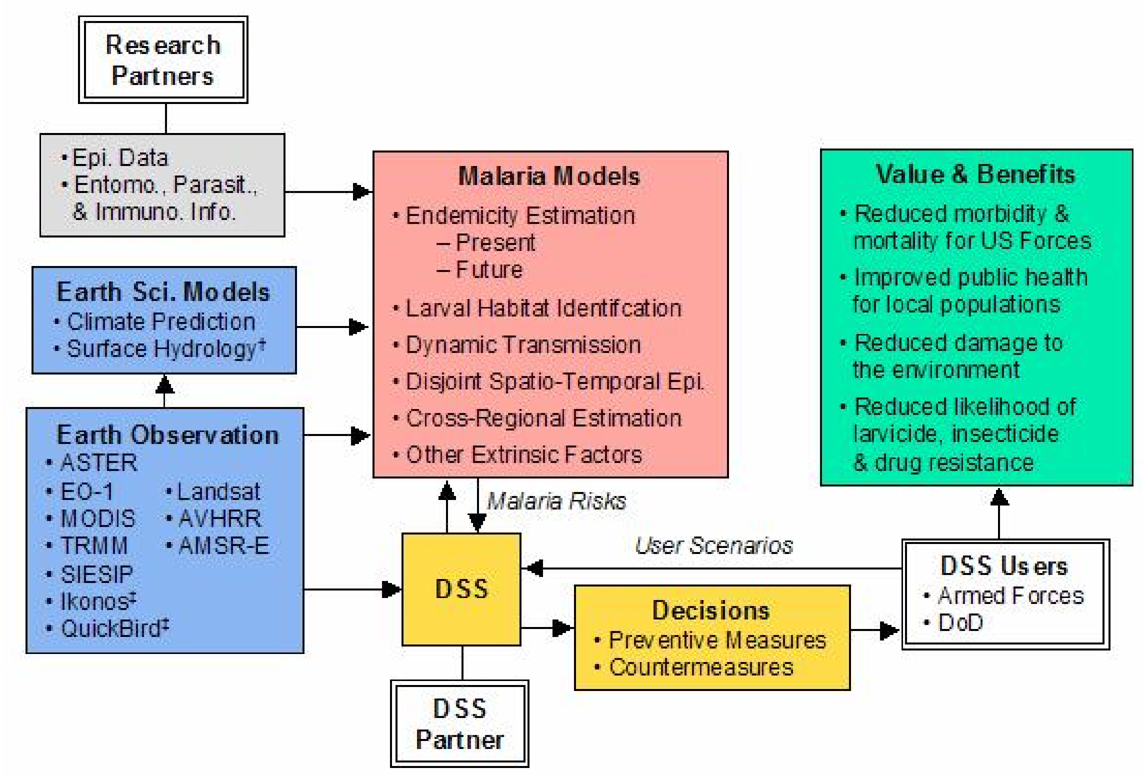



**Figure 1. GSAT Overview**
NASA malaria model output will be pushed by NASA and uploaded by AFSOC. A direct machine-to-machine interface will transfer data to the unclassified GSAT server. The unclassified results will then be transferred to the classified GSAT server.

| | 1985–1999 | 2000–Present | Future |
|---|---|---|---|
| Temperature | SIESIP<br>0.5° × 0.5°<br>monthly | MODIS<br>0.05° × 0.05°<br>8-day & monthly | NSIPP<br>2.5° Lat × 2° Lon<br>monthly |
| Precipitation | SIESIP<br>0.5° × 0.5°<br>monthly | TRMM<br>1° × 1°<br>monthly | NSIPP<br>2.5° Lat × 2° Lon<br>monthly |
| NDVI | AVHRR Pathfinder<br>$8 \times 8$ km$^2$<br>monthly | MODIS<br>$1 \times 1$ km$^2$<br>16-day & monthly | MODIS<br>$1 \times 1$ km$^2$<br>monthly averages† |

† averaged from two previous years

**Table 1. Climatic and Environmental Data Sets and Their Spatial and Temporal Resolutions**
These data will be used for assessing malaria risks based on retrospective analysis and forecasting.




† When models with higher resolution become available
‡ Very limited amount

**Figure 2. Integrated System Solution Diagram**